

Representation of Series and Transforms in engineering subject, using a Web User Interface for GNU Octave

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Abstract. This article shows the experience of using a web user interface (UI Web) for GNU Octave, in order to represent mathematically and graphically the Fourier series and transforms that are studied in one of the units of an introductory subject in the telecommunications area, in the Electronic Engineering program from Ricardo Palma University (URP), Lima-Peru. Likewise, we show the development of the programming routines to obtain the Fourier series coefficients of some periodic signals, as well as the graphical representations of them in the frequency domain. Also, with the Fourier Transform, from the discrete point of view, some non-periodic signals were analyzed. Finally, we show the averages of the evaluations obtained in the thematic unit of interest, through a trend graph with a positive slope.

Keywords: Web User Interface, Fourier series, Discrete Fourier Transform, Octave Online.

1 Introduction

Nowadays, computer tools for numerical calculation have become one of the main supports in science education, and this because many of them grant ease in terms of 2D and 3D graphic representations, animations, logic programming routines, graphical user interfaces, symbolic operations, numerical operations, and other features. Likewise, such tools are available for various operating systems, including those that are freely available as is the case with Linux. In this way, among some of the most common computer tools that have been used by various universities in the world in the field of research and development; thus, we have: Matlab, Maple, Scilab, Mathematica, GNU Octave, etc.; as well as, there are various programming languages that allow or facilitate the teaching of science in the classroom, particularly in some engineering programs. So, we have C ++, Java, Python, R, Julia, etc. And, not only these computational tools can be used from a personal computer, but they are also possible to use from various portable electronic devices such as Tablets, Cell phones, iPad, Laptops, etc., which offers greater versatility for the student allowing him to simulate, calculate, model, program, graph, among other actions, while moving or being outside his study center. In most universities that offer engineering programs it

is necessary to teach several science subjects from the first semesters of study, as is the case with physics, chemistry and mathematics; and, according to the engineering specialty, it is decided to include more or less of these subjects in the curriculum. Particularly, in Electronic Engineering program from Ricardo Palma University in Lima-Peru, according to the 2015-2 Curriculum Plan [1], five math courses, 4 physics courses and 1 chemistry course are taught, which are dictated in the first two years of study. In this way, we form a solid basis in the student to face specialized subjects that require an understanding of this previous theory; such is the case of the subjects of the area of Process Control and Telecommunications. Specifically, in this last area, students require knowledge of a very useful mathematical theory to analyze electrical signals in the frequency domain; for that reason, current curriculum contains the subject Signals and Systems in the Fifth Academic Semester, and the subject Telecommunications I in the Sixth Academic Semester. Then, the student continues with the other subjects until they reach those that are clearly of specialty.

It is like that, the purpose of this article was to represent the Series and Fourier Transform in the subject Telecommunications I. Thus, we use a User Interface via the Web for a free access computer tool known as GNU Octave, in order that the student does not need to go to a computer lab to use this tool. Rather, on the contrary, it would be enough to remain in the classroom and choose to use a mobile device with Android or iOS operating system, or as also through a laptop, Apple tablet or iPad. Whereby, to measure such independence in the use of a personal computer in the classroom, it is complemented by the average scores obtained in the evaluation of the learning unit related to Fourier Theory, the results being satisfactory compared to the academic semesters of previous years.

1.1 GNU Octave

GNU Octave is a scientific programming language that has a powerful math-oriented syntax, with integrated plotting and visualization tools. In addition, it is a free distribution software that runs on GNU / Linux, macOS, BSD (Berkeley Software Distribution) and Windows. Moreover, likewise, it is compatible with many Matlab digital computing software scripts [2]. It is also known as free Matlab equivalent and is part of the GNU operating system software packages. Likewise, in March 2019, the publication of the GNU Octave version 5.1.0 was announced, which is available to be downloaded from the official link.

1.2 Web User Interface

Web user interface is a digital and robust platform, accessed directly from the web or internet, allowing direct and easy interaction with the user. Specifically, web user interface of this article emphasizes that corresponding to the GNU Octave scientific programming language and its name is Octave Online.

Further, we use this interface by thousands of students, educators and researchers around the world to study machine learning, control systems, numerical methods, and much more [3]. Likewise, the main feature of this web user interface is that it can be

accessed directly after an immediate scan in the Google search engine. For it, you must type the phrase octave online, and immediately a list of links related to it is received; but clicking on the first search result allows us to enter this interface to be able to use it freely. Then, figure 1 shows a screenshot of the Web User Interface obtained after your Google search.

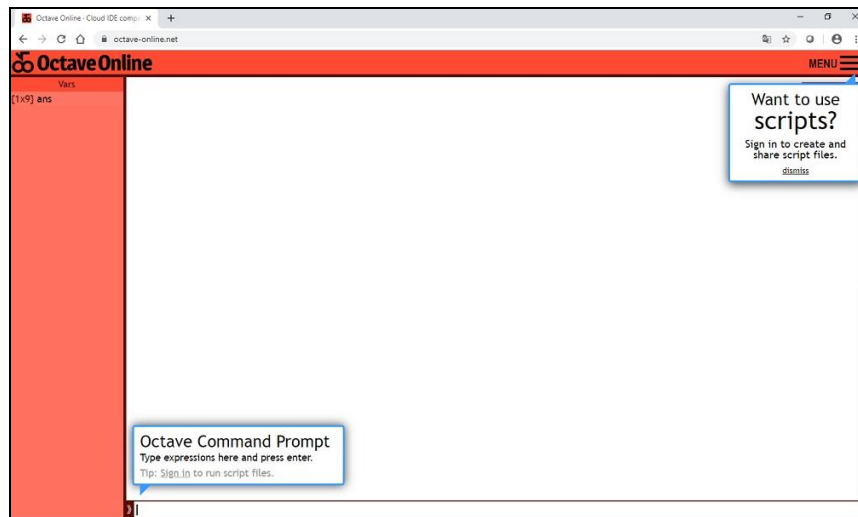


Fig. 1. Screen capture of the Web User Interface for GNU Octave programming language, made from the Google search engine.

In the upper right, from the previous figure, we observe the menu option; and, when you click on it, the path to access through a gmail account is displayed, which allows access to more tools. For example, upload files, create new files, and refresh files, among others.

2 Methodology used with Web UI

This section describes the methodology used with the Web UI, to represent the Series and Fourier Transform in a course of the URP Electronic Engineering program. For this, below are the main characteristics of this subject, as well as the procedure used in the classroom, and the respective simulation examples performed.

2.1 Course of Telecommunications I

The subject of Telecommunications I belongs to the Sixth academic semester of the Program of Electronic Engineering of the URP. Likewise, according to the 2015-2 curriculum, it has 6 hours per week of which 4 are used to teach the theoretical and

practical part in a conventional classroom, while the other 2 hours are used for the development of experimental laboratory guides in the corresponding laboratory. In the next table, we show the name of each thematic unit of this subject, with the number of sessions and academic hours to cover your classroom dictation as well as the development of laboratory experiences.

Table 1. Thematic Units of Telecommunications I course.

| Unit number | Thematic Unit Name | Sessions | Academic hours |
|-------------|--|----------|----------------|
| 1 | Communications systems. | 4 | 12 hours |
| 2 | Linear Systems and Frequency Representation. | 6 | 18 hours |
| 3 | Amplitude Modulation and Demodulation. | 8 | 24 hours |
| 4 | Angular Modulation and Demodulation. | 10 | 30 hours |
| TOTAL: | | 28 | 84 hours |

The topic of Series and Fourier Transform belongs to the second thematic unit of the subject Telecommunications I, and it takes place in three classroom sessions using a fraction of hours of the total corresponding to that unit. In this way, the need to learn, understand and use this Fourier Theory it is essential because in subsequent subjects, the student must master the concepts related to the frequency domain. So, that in this way it is possible to perform the frequency analysis of the electrical signals that are transmitted and / or received, in order to use it in audio and video communications.

2.2 Temporary representation of periodic and non-periodic signals.

For the temporary representation of the periodic signals, in the Octave Online, two variables are required; one temporary and the other for the amplitude. Examples of periodic signals are square wave, sawtooth, triangular, or some other arbitrary signal that shows periodicity. Then, in equations (2), (3) y (4), the mathematical expressions of four periodic signals are shown [4], [5]. Then, in figures 2 and 3, we present their respective time graphs obtained with lines of code developed in the Octave Online.

$$+1, \text{ for: } 0 < t \leq 0.5 * T \quad (1)$$

$$-1, \text{ for: } 0.5 * T < t \leq T$$

$$(4 / T) t - 1, \text{ for: } 0 < t \leq 0.5 * T \quad (2)$$

$$- (4 / T) t + 3, \text{ for: } 0.5 * T < t \leq T$$

$$- 4, \text{ for: } 0 < t \leq T/3 \quad (3)$$

$$0, \text{ for: } T/3 < t \leq 2 * T/3$$

$$\begin{aligned}
& 4, \text{ for: } 2*T/3 < t \leq T \\
& -(4/T)t + 2, \text{ for: } 0 < t \leq 0.25*T \\
& (4/T)t, \text{ for: } 0.25*T < t \leq 0.5*T \\
& 1, \text{ for: } 0.5*T < t \leq 0.75*T \\
& 0, \text{ for: } 0.75*T < t \leq T
\end{aligned} \tag{4}$$

On the other hand, in the case of non-periodic signals, two examples were established where one is generated mathematically with the temporal variable to square. Moreover, we obtained the other by reading an audio file with WAV extension corresponding to a fraction of voice signal. See figure 4.

2.3 Frequency representation of periodic and non-periodic signals.

For the frequency representation of the periodic signals, in the Octave Online, Fourier Series Theory is required to determine the coefficients a_0 , a_n and b_n , that will allow to represent the periodic signal with a sum of sinusoidal functions, with different frequencies and amplitudes. Next, the mathematical representation of the Fourier Series is shown as well as the expressions for the calculation of the three coefficients (see equation 5). For this reason, we decide to use the Octave Online complemented with functions that allow developing a numerical integral in a literal way.

$$\begin{aligned}
f(t) &\sim \frac{a_0}{2} + \sum_{n=1}^{\infty} \left[a_n \cos\left(\frac{2n\pi}{T}t\right) + b_n \sin\left(\frac{2n\pi}{T}t\right) \right] \\
a_0 &= \frac{2}{T} \int_{-T/2}^{T/2} f(t) dt, \quad a_n = \frac{2}{T} \int_{-T/2}^{T/2} f(t) \cos\left(\frac{2n\pi}{T}t\right) dt, \quad b_n = \frac{2}{T} \int_{-T/2}^{T/2} f(t) \sin\left(\frac{2n\pi}{T}t\right) dt.
\end{aligned} \tag{5}$$

In this way, for frequency representation; first, the Fourier Series coefficients had to be determined in the case of the four periodic signals. This was obtained with support from the INT function, which was responsible for developing the literal integral to later evaluate it in each range. We obtained the coefficients, then, we proceeded with a programming based on the syntax of the FOR to proceed with a finite sum of sinusoidal signals. Then, the left side of Figure 5 shows the result of obtaining the Fourier Series coefficients for the signal of equation 1, while on the right side we show the result of a sum of 100 sinusoidal functions. In the same way, in the figure 6, on the right side we show the result of a sum of 20 sinusoidal functions for equations 3 and 4.

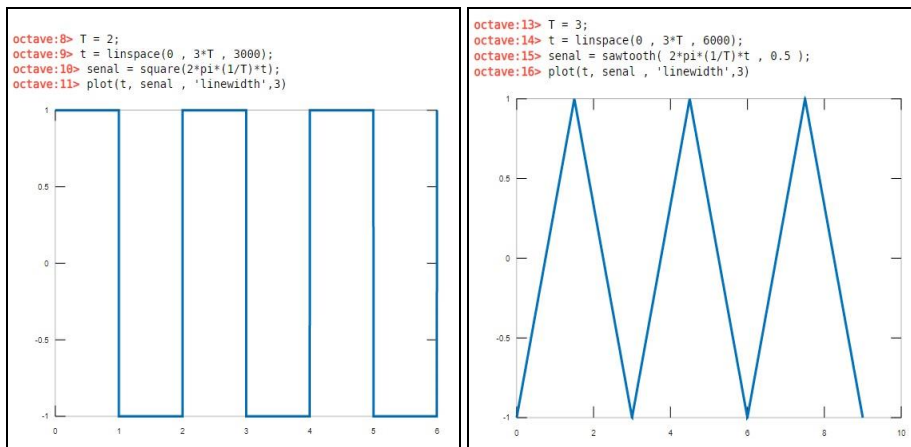


Fig. 2. Screen capture of the programming code developed in Octave Online for the graphic representation. Left: equation (1) signal. Right: equation (2) signal.

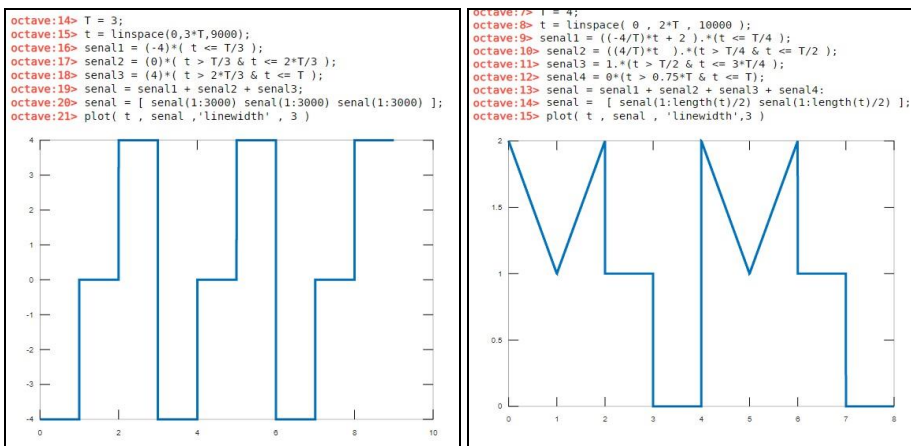


Fig. 3. Screen capture of the programming code developed in Octave Online for the graphic representation. Left: equation (3) signal. Right: equation (4) signal.

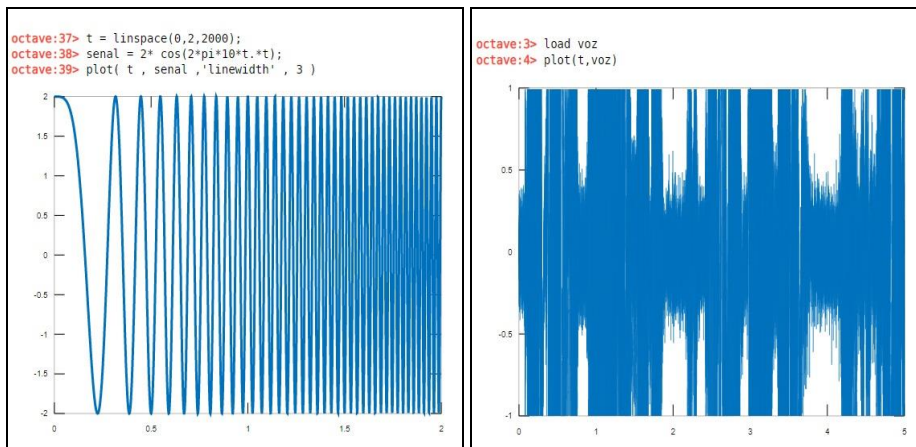


Fig. 4. Screen capture of the programming code in Octave Online for the graphic representation of two non-periodic signals. Left: temporal variable squared. Right: voice fraction.

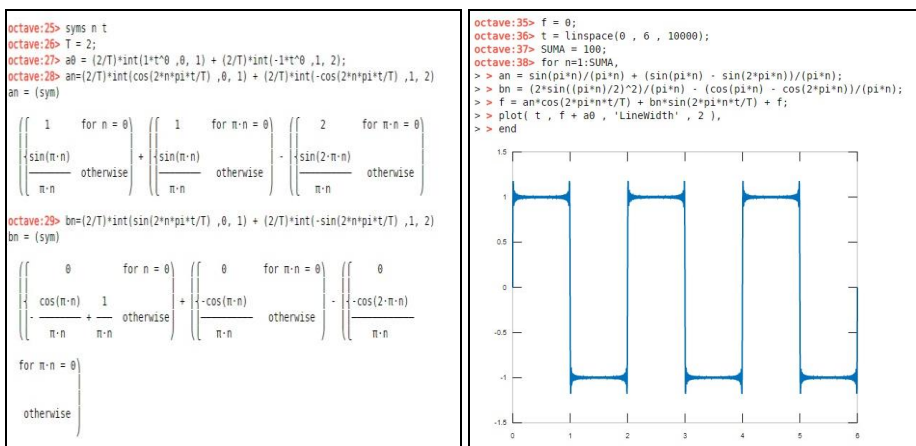


Fig. 5. Screen capture of the programming code in Octave Online. Left: obtaining the Fourier Series coefficients. Right: graph with sum of sinusoidal functions.

On the other hand, in the case of the frequency representation of a non-periodic signal, the Fourier Continuous Transform is the most indicated. Nevertheless, considering that non-periodic signals are digital because they have been represented on a computer, it was decided to use the Discrete Fourier Transform. For this, the FFT function of the Octave Online was used, with its correspond parameters. Then, the mathematical expression used, and the programming statement used in the Octave Online are shown. See figure 7.

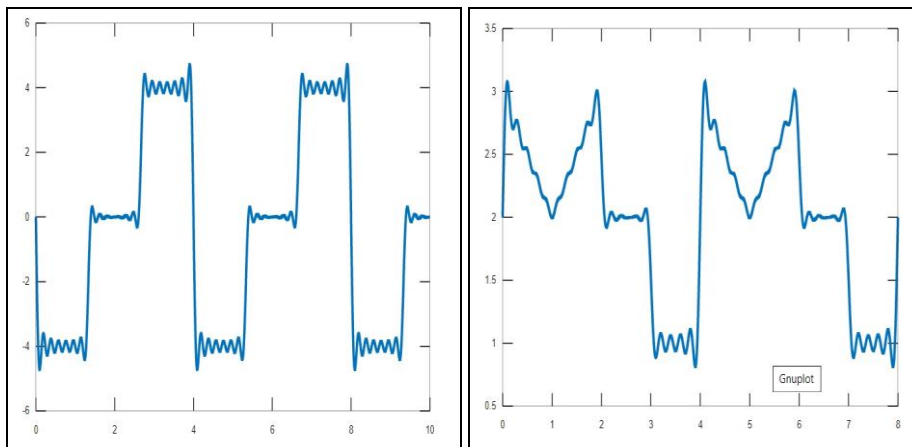


Fig. 6. Screen capture of the Octave Online. Left: Graph with sum of sinusoidal functions of equation 3. Right: Graph with sum of sinusoidal functions of equation 4.

$$X(k) = \sum_{n=0}^{N-1} x(n) e^{-j2\pi kn/N}, \quad k = 0, 1, \dots, N-1 \quad (6)$$

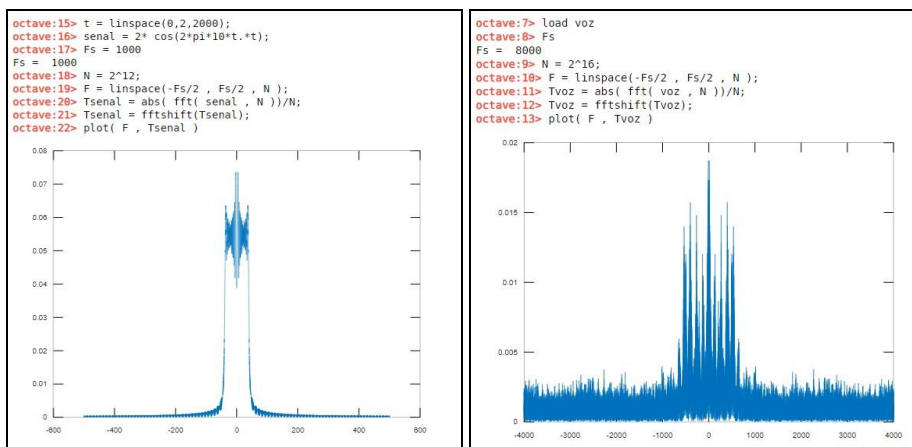


Fig. 7. Screen capture of the programming code in Octave Online to obtain Fourier Transform. Left: temporal signal squared. Right: fraction voice signal.

2.4 Evaluation of students with the Fourier Theory

The evaluation of the students regarding the Fourier Theory, it was carried out in the first qualified practice of the subject Telecommunications I. We always do this

evaluation in the third or fourth week of classes and we developed in two different ways. Thus, on some occasions, the evaluation is done in a traditional way in the classroom, being one of the questions obtaining the Fourier Series coefficients. While on other occasions the approach to homework is chosen, where students are motivated to use scientific computing software to determine the Fourier Series coefficients, then evaluate them and graph the sum of sinusoidal signals. However, Ricardo Palma University has an updated license of Matlab scientific computing software, but this only is use in the computer labs of the university itself. Therefore, we force students to use free software to develop their simulation tasks.

3 Results and conclusions

The use of the Octave Online web interface has presented favorable results regarding his willingness to be employed in the classroom, as it was done in the works [6], [7], [8], [9] y [10]. Whereby, it has not been necessary to have a computer lab to run the simulations and expand the knowledge of the Fourier Theory. In this way, Table 2 represents the average of the first evaluated practice that corresponds to the topic of interest; we observe that there is an increase in the semester 2019-1, compared to previous semesters. Well, this confirms that the use of this interface began during this period and has led to a better student performance in terms of evaluation. Similarly, with the information obtained in the last semesters, we represented a trend graph in Figure 8. In addition, Table 2 shows that in some semesters, the rating was higher, and this is because the evaluations were not uniform; on the contrary, we used two different methodologies. They were explained in the previous section.

Table 2. Average of practice 1 for the last 8 academic cycles.

| Item | Academic Semester | Practice N° 1 Evaluation |
|------|-------------------|--------------------------|
| 1 | Semester 2019-1 | 15.4444 |
| 2 | Semester 2018-2 | 13.0000 |
| 3 | Semester 2018-1 | 14.0000 |
| 4 | Semester 2017-2 | 13.2000 |
| 5 | Semester 2017-1 | 14.3750 |
| 6 | Semester 2016-2 | 15.6429 |
| 7 | Semester 2016-1 | 13.1667 |
| 8 | Semester 2015-2 | 14.4286 |

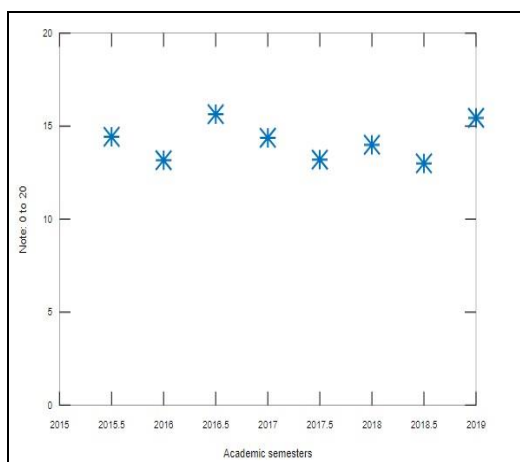


Fig. 8. Trend graph with positive slope.

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